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# INTEGRATED OPTIMIZATION OF HYBRID ENERGY SOURCES FOR RESIDENTIAL BUILDINGS

Anatoliy PAVLENKO<sup>1\*</sup>, Dariusz MIKIELEWICZ<sup>2</sup>

<sup>1</sup> Kielce University of Technology, al. Tysiąclecia Państwa Polskiego 7, 25-314 Kielce Poland

<sup>2</sup> Gdańsk University of Technology, al. Zwycięstwa 27 80-219 Gdańsk Poland

\* **Corresponding author.** Email address: [apavlenko@tu.kielce.pl](mailto:apavlenko@tu.kielce.pl)

**Abstract** – The optimization of hybrid building energy systems is commonly addressed using two main approaches: model-based and rule-based energy management strategies that ensure operational stability, and heuristic or algorithmic methods designed to optimize multiple objectives such as operational cost, CO<sub>2</sub> emissions, and system reliability. However, these approaches are often insufficiently validated with respect to energy demand sensitivity, limiting their robustness under dynamic and uncertain operating conditions. This study proposes an integrated energy forecasting and management framework that combines real-time energy management with intelligent load control based on dynamic building energy modeling. Despite significant progress in hybrid renewable energy system control, existing solutions frequently lack unified and computationally efficient algorithmic architectures capable of simultaneously addressing multiple renewable energy sources, energy storage systems, and demand response. Moreover, many approaches exhibit limited effectiveness in handling complex multi-objective optimization problems in real-time applications.

To overcome these limitations, the proposed framework integrates machine learning-based energy demand forecasting with a two-level optimization strategy supported by adaptive parameter control and parallel evaluation. The framework enables real-time decision-making while maintaining computational efficiency. By coordinating hybrid renewable energy systems with conventional power supply infrastructure, the proposed approach reduces carbon emissions and energy consumption while ensuring occupant comfort, thereby demonstrating strong potential for practical deployment in smart and energy-efficient buildings.

**Keywords** – *Building dynamic simulation; building energy model; energy demand forecasting; hybrid renewable energy*

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